Agronomical use of sewage sludge from Urban Waste Water Treatment: heavy metals in *Zea mays* plants

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The Urban Waste Water Treatment Directive (91/271/EEC) aims to encourage the use of sludge whenever appropriated ; the sewage sludge is a product of wastewater treatment which could find a reutilisation in the agricultural field.

The necessity to find a solution to the sewage and biomass disposal has led to the development of techniques based on natural reuse of agricultural soils.

In this way it represents, through a closed loop system, a source of all the nutritional elements which have been removed by the agriculture.

The sewage sludge application on soils represents an alternative to the traditional stock strategies ; more convenient, from the economical point of view, than incineration or disposal in landfill, it also contributes to solve the sewage sludge recycling issue.

The accumulation of sewage sludge from urban wastewater treatment plants is a growing environmental problem. Using such sludge as fertilisers or as organic soil regenerators seems an attractive possibility because it would enable valuable components (organic matter, N, P and other nutrients necessary for plant growth) to be recycled (Hernandez *et al.*, 1991 ; Smith, 1996 ; Zufiaurre *et al.*, 1998). However, this practice represents a potential threat to the environment because of the possible high heavy metal content, a problem that may be aggravated if the toxic metals are mobilised in the soil to be taken up by plants or transported in drainage waters (Alonso *et al.*, 2002 ; Angelidis and Gibbs, 1991 ; Mingot *et al.*, 1995).

Various methods have been proposed to dispose of the sludge either in the form of liquid slurry or dried sludge. The land application technique is one of the methods being considered and is thought to be very effective and efficient. Sludge may be applied to agricultural land, forest, disturbed land or dedicated disposal sites (Murphy *et al.*, 2000 ; Planquart *et al.*, 1999 ; Bhogal *et al.*, 2003 ; Scancar *et al.*, 2000 ; Alvarez *et al.*, 2003 During *et al.*, 2003 ; Walker *et al.*, 2003).

The application of stabilized sewage sludge to the land has therefore become an attractive option. This practice could solve two problems : (i) a potential source of pollution is reduced in size, and (ii) soil productivity is favoured and the need for synthetic fertilizers reduced (which has inherent economic benefits). Sewage sludge is a good source of plant nutrients such as N and P (Sims and Pierzynski, 2000 ; Shober *et al.*, 2003 ; Martınez *et al.*, 2003) and it has large amounts of organic matter that can improve the physical and biological properties of the soil (Logan and Harrison, 1995 ; Caravaca *et al.*, 2002). The reclaim of these biomasses for fertilization could establish more benefits because it allows exploiting the fertilizer proprieties of the material, representing a strong potentiality of nutritive elements as nitrogen, phosphorus, potassium, calcium and magnesium and even more of organic matter.

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However, the presence of toxic elements, in particular heavy metals as zinc, copper, nickel, cadmium, lead, chrome and mercury, with high concentrations, makes their management tangled. It has been suggested that applying sewage sludge to soil might provide metals in potentially toxic, labile forms (McBride, 1995).

The increased production of wastes and the growing awareness of their potential dangers have therefore made it necessary to make quantitative measurements of their environmental impact (Fuentes *et al.*, 2006).

The presence of significant quantities of heavy metals in urban sewage sludge reflects the source of the sewage material both industrial and residential. The metals are concentrated in the sludge as a result of their association with settleable solids during primary and secondary wastewater treatment processes (Sterritt and Lester, 1983). Because the level of contaminants and the nutrients can vary widely depending on the nature and on the source of sludge, born the necessity to control monthly the composition of the sewage sludge produced by the plant in order to determine the homogeneity of the product and so the possibility to control the effect in the agricultural use.

The aim of this study was to control monthly the sewage sludge composition, in order to verify its homogeneity and to grow up maize under experimental conditions, in order to evaluate the connection between application of sewage sludge and residual heavy metals concentration in the different plants part after a manure system composted by different cross levels of sewage sludge and mineral nitrogen (Urea).

▼ Table 1 – Soil texture.

TEXTURE			
Clay%	*Slime%*	*Silt%*	*Sand%*
5,75	20,1	30,6	43,55

▼ Table 2 – Chemical and physical properties of soil and sewage sludge.

Properties	Background soil	Sewage sludge
Total nitrogen (%)		2,19
N-NH_4 (mg kg^{-1})		4,5
Exchangeable Potassium (mg kg^{-1})	64,5	320,68
Organic matter%	1,6	19
Phosphorus tot (mg kg^{-1})	120,1	230,12
Carbon organic (g kg^{-1})	9,35	217,36
pH	6,93	7,9
C.E.C. meq/100g	14,47	-
Heavy metals (mg kg^{-1})		
Cd	0,50	< 0,01
Cr	33,53	52,00
Cu	34,76	286,21
Pb	25,88	113,53
Zn	141,28	1063,42
Hg	< 0,01	2,41

Materials and methods

Soils and sewage sludge used

The acid soil at the experimental site belongs to AMAGA the Urban Waste Water Treatment plan sites in Abbiategrasso, Milan, Italy. The soil has the texture characteristics as shown in Table 1, with a pH value between 6.5 and 7.

The sewage sludge is an anaerobically digested and subsequently dewatered in a belt filter press to attain a concentration of approximately 20-25% total solids coming from as the soils from the AMAGA plant as the results of the urban waste water treatments. The chemical and physical properties of the soil and sewage sludge are presented in Table 2.

Four replicates of each lyophilised and sieved sample were characterised according to different agronomic parameters : pH, moisture content, organic matter content, total nitrogen and total phosphorus. These parameters were determined by standard analytical methods, except in the case of nitrogen, which was determined by elemental analysis. The quantity of the various macroelements and metals were ascertained by ICP and elementary analyser in the case of carbon and nitrogen.

Field experiment and experimental design

We had a total randomized block scheme (Table 3) with three different sewage sludge dosages (0 – 5 ton/ha DM – 10 ton/ha DM) and three different mineral nitrogen dosages, using urea (0 –100 kg/ha –200 kg/ha) crossed in nine thesis with four replications each.

The experimental site was composed by four rows of nine tanks each, the maize was planted in row on top-soil, in quantity of 8 plants for tank (0.8249 m^2) ; we had a drip irrigation following a water balance system based on the meteorological data (sun radiation, rain, air moisture, temperature…) gathered daily.

During the plant cycle we have, every time it was possible, collected the leachate in order to evaluate the possibility to lose nutrients for bleaching while to contaminate in some way the ground-water.

After the harvest, we have considered separately grains, straw and cob and we have first dried at 105° C and then cut up to the 0.5 mm dimension, in order to be ready for the digestion (0.5 g in 10 ml concentrated nitric acid, microwave technique).

After digestion we used the ICP for what concerning the following heavy metals ; Cd, Cr, Cu, Pb, Zn, Hg and P and K content.

While we have used the elementary analyser to obtain the concentration of nitrogen and carbon and the FIAstar™ 5000 Analyzer for the ammonium and nitrate.

All the data were treated with SPSS statistic analysis program.

Results and discussion

We had analysed each month the composition of the sewage sludge produced by the Urban Water treatment plant of Abbiategrasso, Milan, Italy, which as the characteristics shown in table 4.

We had considered and analysed the nutrients and the following metals : Cd, Cr, Cu, Pb. Zn, Hg and we could find out the variability of the composed produced by this plant.

In the graphics 1 and 2, we can observe the changing in the composition of the sewage sludge due to the heterogeneity of the waste in entrance compared with the limits imposed by the law for agriculture use.

In the nine thesis we have given to the plants different quantity of nitrogen in different forms : nitrogen from sewage sludge and mineral nitro-

Table 3 – Experimental field : randomized block scheme.

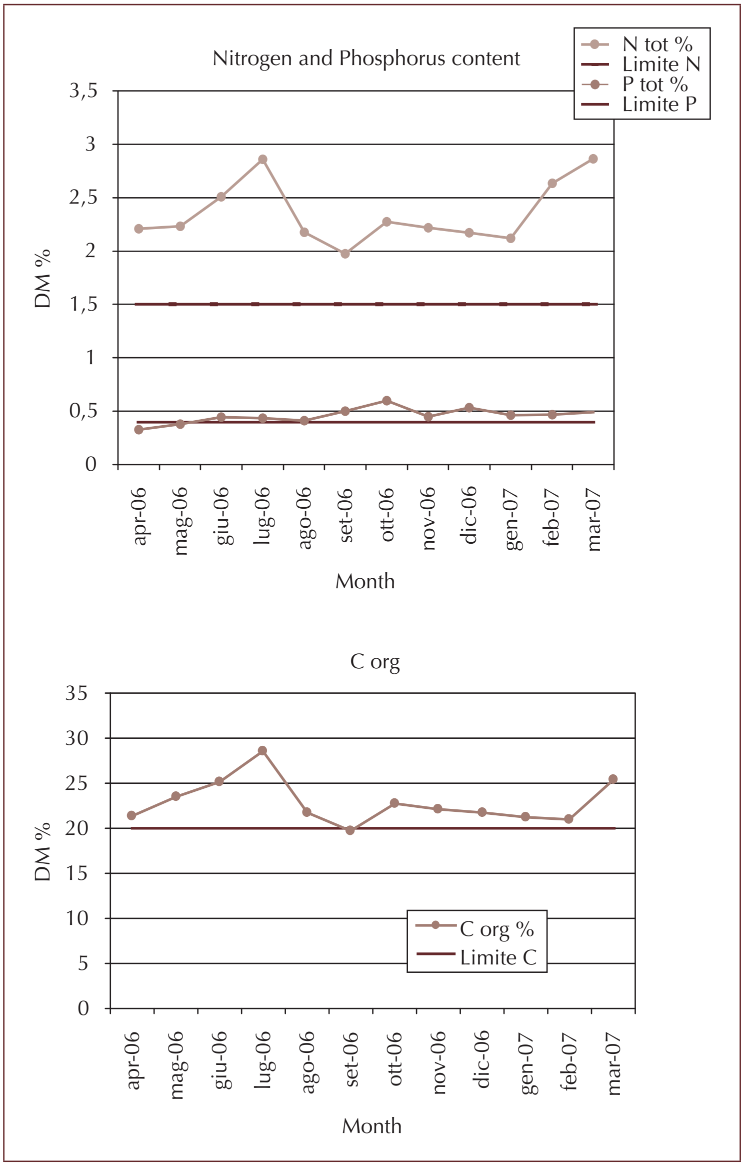
MAIZE					Sewage sludge ton/ha	N_min kg/ha
37	54	55	72		0	0
38	53	56	71		5	0
39	52	57	70		10	0
40	51	58	69		0	100
41	50	59	68		5	100
42	49	60	67		10	100
43	48	61	66		0	200
44	47	62	65		5	200
45	46	63	64		10	200

Table 4 – Pant characteristics.

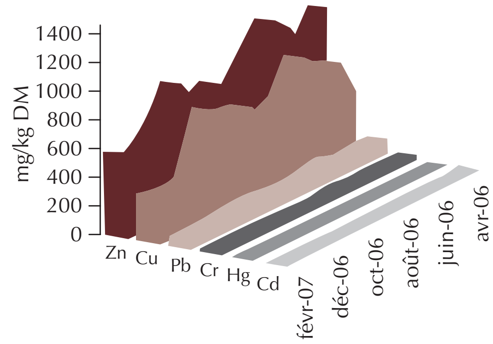
Sewerage	Mixed
Inhabitants served	25.000
Industries served (as Inhabitants n°)	15.000
Total inhabitants (n°)	40.000
Daily discharge (m3)	15.000
Special waste (n°)	110

Table 5 – Nitrogen dosage.

Thesis	N - sewage sludge kg N ha^{-1}	N sewage sludge available kg N ha^{-1}	N urea before sowing kg N ha^{-1}	N urea – cover time kg N ha^{-1}	N – available for the plant kg N ha^{-1}
1	0	0	0	0	0
2	171	86	0	0	86
3	342	171	0	0	171
4	0	0	50	50	100
5	171	86	50	50	186
6	342	171	50	50	271
7	0	0	100	100	200
8	171	86	100	100	286
9	342	171	100	100	371



▲ **Graphic 1 – Nitrogen, Phosphorus and Carbon concentration in sewage sludge.**



	Limits mg/kg DM	Average value mg/kg DM
Zn	2500	856.4
Cu	1000	622.7
Pb	750	114.6
Cr	300	33.53
Hg	10	2.30
Cd	20	<0.1

▲ **Graphic 2 – Metal content in sewage sludge.**

gen, given as urea (Table 5) and of course we considered the natural soil supply.

We have evaluated the following parameters in the different parts of the plant (grains, straw and cob) after the harvest : Cd, Cr, Cu, Pb, Zn, Hg.

We couldn't find any significant variation in terms of concentration of Cu, Cd, Cr, Pb an Hg, maybe because was just one year experimental time, but we had some interesting data about the zinc.

The concentration inside the grain which increase as the sewage sludge dosage is shown in the graphic 3, ranging from value of 22.63 ± 3 mg/kg DM to 27.69 ± 2.7 mg/g.

The statistic analysis, done with SPSS confirms the significant role of the sewage sludge in the zinc increased concentration in grains as the graphic 4, while decreased in straw, having an opposite effect due to the sewage sludge dosage as reported in the graphic 4.

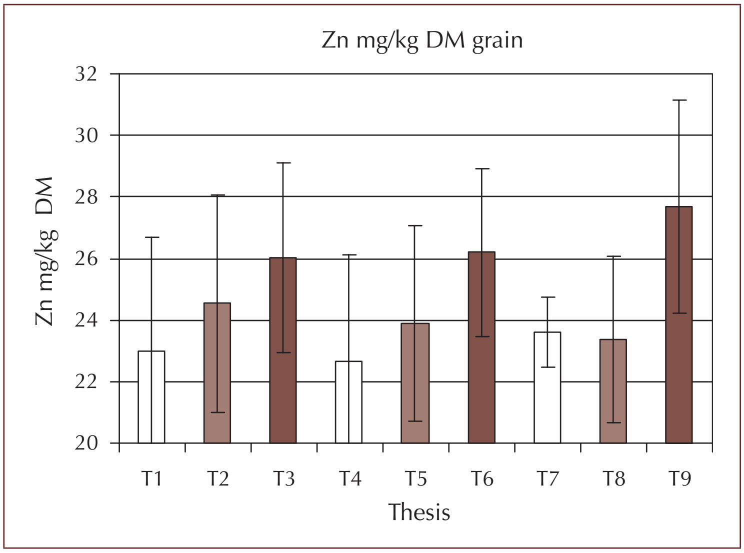
In the leachate we did not find any particular results, in terms of connection with the manure system. All the metals values were in the range foreseen by the law for the surface water.

Conclusion

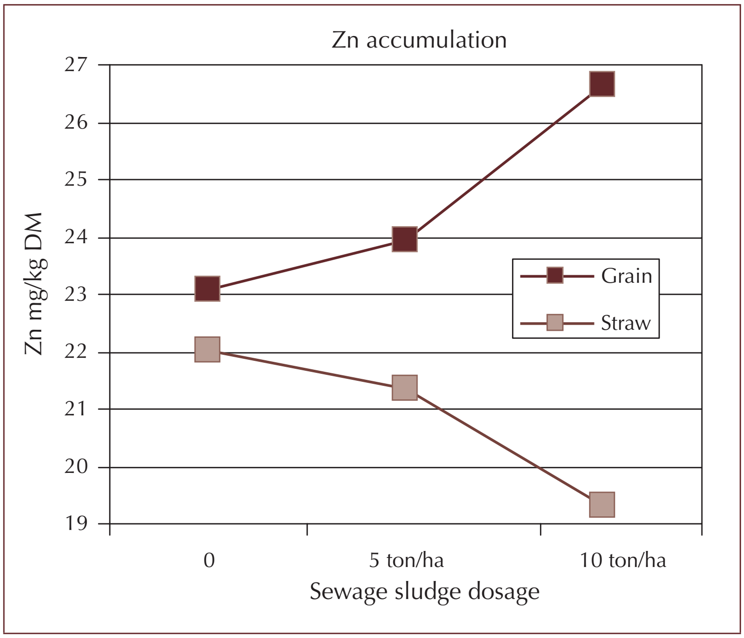
This work reports preliminary results of a one year growth. In this first session of the project, we have evaluated that the sewage sludge is a valuable source of nitrogen, completed with the mineral one, enable to obtain good results (up till 15 ton of dry matter for hectare) in terms of maize production and its heterogeneity in the long period.

The critical point in their use is the accumulation of heavy metals, which were not found in dangerous concentrations inside the plants ; while it was observed that zinc significantly accumulates with higher level (maximum 27.69 mg/kg DM) in the grains of the plants treated with higher sewage dosage. This behaviour is probably connected with high availability of zinc in soil and the sewage sludge presence, while is going to be very interesting to understand how this metal moves inside the plant structure in order to confirm the data concerning the different levels present in the straw compare with the grains one. This behaviour could be connected with the extraction of nitrogen from the soil to the plant, and the zinc transporters can be connected in some ways to the nitrogen ones.

The prosecution of this work will focus on the effects in time (three years) of the sewage sludge and how the environmental system will respond at their presence, in terms of nutrient availability and metals accumulation. ❒



▲ Graphic 3 – Zinc concentration in grains.



▲ Graphic 4 – Zn concentration in grain and straw depending on sewage sludge dosage - sign. › 0.05.

Abstract

The Urban Waste Water Treatment Directive (91/271/EEC) aims to encourage the use of sludge whenever appropriate ; the sewage sludge is a product of wastewater treatment which could find a reutilisation in the agricultural field.
The necessity to find a solution to the sewage and biomass disposal has led to the development of techniques based on natural reuse of agricultural soils.
In this way it represents, through a closed loop system, a source of all the nutritional elements which has been removed by the agriculture.
The sewage sludge application on soils represents an alternative to the traditional stock strategies ; more convenient, from the economical point of view, than incineration or disposal in landfill, it also contributes to solve the sewage sludge recycling issue. The aim of this project is to grow up maize under experimental conditions, in order to evaluate the nutrients contribution of the sewage sludge on the final production, while observing the connection between application of sewage sludge and residual heavy metals concentration in the different plant parts.

Résumé

La directive sur le traitement des eaux usées (91/271/CEE) a pour but d'encourager l'usage approprié des boues. Les boues d'épuration sont des produits issus du traitement des eaux usées qui peuvent être réutilisés dans le domaine agricole. La necessité de trouver une solution pour l'élimination des eaux usées et de la biomasse a mené au développement de techniques basées sur le recyclage naturel sur les terres agricoles.
Dans ce contexte, cela représente dans le cadre d'un cycle fermé, une source d'éléments nutritifs, lesquels ont été retirés par l'agriculture. L'application des boues d'épuration sur les sols représente une alternative aux stratégies traditionnelles, plus appropriée d'un point de vue économique que l'incinération ou l'entreposage en décharge, cela contribue aussi à résoudre la problématique du recyclage de ces boues.
L'objectif du projet décrit dans cet article est de faire pousser du maïs sous conditions expérimentales afin d'évaluer la contribution nutritive des boues sur la production finale et d'observer la connexion entre épandage des boues et concentration en métaux lourds dans les différentes parties de la plante.

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